A SYSTEMS INVESTIGATION INTO THE STATISTICAL MODELING OF SELECTED DAILY CLIMATOLOGICAL MEASURES IN EXTREME CLIMATES OF THE UNITED STATES

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Wallace Page Buran

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A SYSTEMS INVESTIGATION INTO THE STATISTICAL MODELING

OF SELECTED DAILY CLIMATOLOGICAL MEASURES

IN EXTREME CLIMATES OF THE UNITED STATES

Approved:

Cecil G. Johnson, Chairman

Thomas B. [illegible]

Douglas C. Montgomery

Date approved by Chairman: August 21, 1978

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PREFACE

The relationships between living organisms and the external environments in which they exist are the focus of considerable research interest (13). One aspect is the interaction between organisms and climatological conditions. Several species of plant life exist only in desert climates, while other plant species exist only in tropical environments. Still other species have adapted to and exist in both climates. Likewise, animals have learned to adapt to many climates, man being a notable example.

Man's method of adaptation differs from that of other animals. His adaptation comes primarily through modification of external conditions rather than evolutionary physiological changes. From the irrigation of arid land to the air conditioning of homes, man has modified the external environment to suit his needs and life-style. However, as the population continues to grow and energy supplies become less available and more expensive, better and more efficient use of energy resources becomes increasingly important. One area which could yield useful information toward this end is the study of climatological variables. Knowledge of climatic processes could yield information upon which to design systems to better utilize the finite resources of the world.

A logical first step in understanding climatic processes is the ability to describe their functioning and from this base predict their occurrence. The objective of this work is to investigate the statistical modeling of selected climatological variables in some extreme climates of the United States.

The original concept for this line of investigation was suggested by Johnson (13) and preliminary studies were performed by Garrison (10) and Wray (36). Their results indicate that this line of research can yield important information and lay the foundation for this work.

SUMMARY

This research compared the behavior of climatological variables in extreme climates of the United States to the behavior of the same climatological variables in a more moderate climate. Yuma, Arizona, and Portland, Maine, were selected as examples of extreme climates and Atlanta, Georgia, was selected as the moderate climate. The variables used in this study were Maximum Temperature, Minimum Temperature, Average Temperature, Precipitation, Average Wind Speed, Maximum Wind Speed, and Sunshine Percentage. Data were collected on sixteen days of the year over a varying number of years in each location. The days of the year selected were: January 10, February 4, March 1, March 21, April 10, May 6, June 1, June 21, July 11, August 7, September 3, September 23, October 10, November 6, December 1, and December 21. The methodology used to select the candidate distributions used to fit each variable in each location was based upon a skewness and kurtosis screening. The distributions considered by the methodology were the beta distribution, the uniform distribution, the normal distribution, the gamma distribution, the log-normal distribution, the exponential distribution, and the Pearson distributions. Maximum likelihood estimators were used to fit the candidate distributions to the data and the chi-square goodness-of-fit test was used to test the validity of the modeling.

The methodology indicated that five of the data bases might be modeled by the distributions. However, the chi-square goodness-of-fit test indicated that none of the five data bases were successfully fitted.

The similarities of the skewness and kurtosis of each variable in all locations tend to indicate that the behavior of each climatological variable is similar in extreme climates to its behavior in a moderate climate. Further, this study indicates that statistically modeling climatological variables using a sixteen day sample over a period of years is not an appropriate approach to the study of climatological phenomena. Statistically modeling each day separately over a long period of years appears to offer a more promising approach.

CHAPTER I

INTRODUCTION

The objective of this work is to compare the behavior of climatological variables in extreme climates to their behavior in a more moderate climate. To accomplish this objective, multiple variables in multiple locations were studied to achieve a systems overview of climatological conditions. Data were obtained from selected days of each year over a period of years so that the most extreme ranges could be included. Statistical models were used to summarize the behavior of each variable in each location.

The distinction between weather and climate is important because the subject of this study is climate, not weather. Weather is the state of the atmosphere, as measured by such variables as precipitation, temperature, humidity, cloud cover, wind, etc.; at a particular place, at a particular time. Climate is the state of the atmosphere, with respect to these same variables, at a particular place over a length of time. The time element is the crucial difference. Climate occurs over a time period while weather occurs at an instant of time. In essence, weather is the limit of climate as the time period involved approaches zero.

The strategy was to study selected climatological variables using historic data from two extreme climates and the moderate climate of Atlanta, Georgia. Where possible, an appropriate statistical distribution was fitted to each variable in each climate and distributions obtained were used to determine probabilities for the selected variable. Weather effects such as fronts, high and low pressure systems and the quantity of meteorological data currently collected were ignored and treated as minor fluctuations in climate. No attempt was made in this work to predict weather, rather the focus was on studying daily climate.

Traditionally, studies of climatological variables have dealt with one variable such as precipitation or temperature. These studies, while interesting and quite necessary, are limited since the result is a one-dimensional view of a multidimensional phenomenon. The systems approach, as presented by Wray (36) in his work on the Atlanta climate, involves the modeling of multiple measures of atmospheric conditions to give a better and more precise view of climate at a specific location. A similar systems approach was used in this work.

From the measures of atmospheric conditions kept by the United States Weather Bureau, seven were selected for use in this study. They were:

1) Maximum Temperature--the highest temperature recorded during the twenty-four hour period beginning at midnight measured to the nearest degree Fahrenheit on a dry bulb thermometer.
2) Minimum Temperature--the lowest temperature recorded during the twenty-four hour period beginning at midnight measured to the nearest degree Fahrenheit on a dry bulb thermometer.
3) Average Temperature--the median of the maximum temperature and minimum temperature during the twenty-four hour period beginning at midnight as measured to the nearest degree Fahrenheit.

4) Precipitation--the total liquid and frozen water measured to the nearest one-hundredth of an inch collected during a twenty-four hour period beginning at midnight.

5) Average Wind Speed--the hourly wind speed readings averaged over a twenty-four hour period beginning at midnight measured to the nearest tenth of a mile per hour.

6) Maximum Wind Speed--the maximum wind speed recorded during the twenty-four hour period beginning at midnight measured to the nearest mile per hour.

7) Sunshine Percentage--the total time to the nearest minute that direct sunlight activates the station recorder divided by the total possible time the sunlight could activate the recorder.

The objective in the selection of these variables was to provide a clear, overall systems view of climate at any locale using existing sources of data. The variables selected were subject to minimal human judgmental errors and were measured using standard equipment. Over a period of approximately forty years, the data have been shown to be reasonably reliable. This is not to say that existing data are totally accurate, but simply to say that the probability of error or bias is significantly less for these measures than measures requiring the observer to judge a percentage or direction by sight.

Measures such as cloud cover and sky cover require an observer to make a judgmental decision on what percentage of the sky is covered during a twelve or twenty-four hour period of the day. Thunderstorms or distant lightning measurements are also affected by human judgmental errors. Measurement of prevailing wind direction requires that an observer judge the primary direction of the wind over an entire day. Though all of these measures are collected using procedures outlined by the U.S. Weather Bureau, due to the dependence each of these measures has upon human judgment, the data must be viewed with question. This is particularly true when several different stations are used in the study as personnel are different at each station. Data for variables such as barometric pressure and relative humidity are limited to recent years and the theoretical base is insufficient for use in this study. Other variables such as dew point, degree days, wet bulb temperature, visibility, and ceiling are of limited usefulness or can be inferred from variables included in the study.

The selection of the types of climate to be used in this study was also important. The extremes of temperature and precipitation were used as the basis for extreme selection because there exists a large amount of sound data easily available. Further, temperature is extremely noticeable and has a large effect on energy usage. Likewise, precipitation is extremely noticeable and of utmost importance to those involved in agriculture. The two extreme climatical variations selected were hot-dry and cold-wet. Cold-dry was not selected because a suitable location does not exist within the contiguous United States. Hot-wet was not used because all the variables are not collected by stations in this extreme. A moderate climate was also included to allow comparisons over the maximum spectrum of conditions. The specific locations used to obtain the data were Yuma, Arizona, for hot-dry climate; Portland, Maine, for cold-wet climate; and Atlanta, Georgia, for moderate climate. A summary of the specific climate of each location appears in Appendix C.

These cities have well established United States weather reporting stations that have operated over fifty years at approximately the same locations and heights above sea level. No claim is made that the three selected cities are the most representative locations of that particular climate or that they represent the optimum which could be selected. However, since some climatological variables are not recorded at each station, the locations represent the best compromise between the most extreme or moderate climate and the best sources of data. The selection of the most extreme climate or the most representative example of an extreme climate could form the basis for a substantive study in itself, due to the large number of factors and the quantity of data involved.

The selection of locations for climatological extremes was restricted to the Continental United States. Only those cities within these confines having long established United States Weather Bureau reporting stations were considered. This step was taken to insure that all data used in this study were gathered and recorded by identical equipment according to standard procedures. By restricting the source of data to the United States Weather Bureau records, no adjustments to the data were necessary and variability in the data from sources other than climatic variations was significantly reduced. Therefore, the data used to develop statistical models tend to reflect accurately the actual climatological conditions at the time recorded. Further, the records of the Weather Bureau were easily accessible and relatively inexpensive.

This study involved the daily values of several climatological variables. Several specific days during the year were selected rather than model all 365 days of the year in order to reduce the volume of work for this study. Wray (36) in his work selected sixteen days basing them around the yearly soltices and equinoxes. This represents the extremes of seasonal variations throughout the year. As this selection criterion seems well founded, the days selected by Wray were those used in this study. Further, if the modeling techniques work for this representative sample, it is reasonable to expect that these techniques can be applied to the remaining days of the year.

Wray used the dates December 1, December 21, January 10, February 4, March 1, March 21, April 10, May 6, June 1, June 21, July 11, August 7, September 3, September 23, October 10, and November 6. Notice that December 21 and June 21 are the yearly soltices and March 21 and September 23 are the yearly equinoxes. December 1, March 1, June 1, and September 3 occur twenty days before each equinox or soltice and similarly January 10, April 10, July 11, and October 10 occur twenty days after each equinox or soltice. Finally, February 4, May 6, August 7, and November 6 represent midpoints between a soltice and an equinox. Every month of the year is included in the dates chosen at least once and all seasons as well as change points in the seasons are represented.

The methodology employed by Wray in studying the Atlanta climate required that the data for each day for each variable be tested for trends using autocorrelation and correlation measures. His findings for Atlanta indicate that no trend effect is present over the last thirty-five years.

As the data used in this study were similar to those used by Wray, no specific testing for trends was performed on the data. However, any trend present would have been easily observable in the data base.

In eliminating trend analysis of the data, certain statistical methods were excluded from consideration since they were based upon the assumption that trends exist in the data. Markov-chain models, series analyses, and Bayesian methods were three methods that were specifically excluded as they tend to apply to short-range predictive applications.

The statistical models used in this study were drawn from the set of continuous distributions. No discrete models were employed. The models considered were:

1) Beta Distribution
2) Uniform Distribution
3) Normal Distribution
4) Gamma Distribution
5) Log-normal Distribution
6) Exponential Distribution
7) Pearson Distributions

These distributions cover virtually all those found useful in prior studies and were applied through a uniform methodology.

CHAPTER II

LITERATURE SEARCH

Introduction

The strategy used in this search of the literature revolved around the computerized literature search service provided by the Price Gilbert Memorial Library at the Georgia Institute of Technology and the search of this topic conducted by Wray (36) in 1977.

Through the computerized search service of the Georgia Tech Library, Wray searched three data bases. These bases were: COMPENDEX, which covers the engineering and technological literature; NTIS, which covers the government-sponsored reports and published papers issued by federal agencies, their contractors or grantees; and Meteorological and Geoastrophysical Abstracts, which covers current citations of meteorological and geoastrophysical research. All pertinent citations listed in Wray's Bibliography were studied and many were incorporated into this work.

The data bases used by Wray were extended through May, 1978, to obtain all new citations in those areas and, further, the data bases were searched over the last two years of his search to check their validity As no new articles were found during the last two years of Wray's search, the search is viewed as valid and its results accepted.

In addition, one other data base was searched for this work. The AGRICOLA data base, which covers citations in the agricultural field, was searched. The citations found were also included in this work. The summaries of these data bases are contained in Appendix B.

The work performed by Wray on the Atlanta, Georgia, climate represents a pivotal study in this area. Since this work applied to all the climatological variables used in this study, his work will be discussed in detail here and the results summarized briefly in the discussion under each specific variable.

Wray used daily observations of twelve selected climatological variables for sixteen days over a thirty-five year period ending in 1975. The data were first tested for the presence of trends by correlation and autocorrelation techniques. Then an attempt was made to fit each day's observations with a statistical distribution. Any distributions fitted were tested by use of the Kolmogorov-Smirnov or chi-square goodness-of-fit tests.

While Wray's work demonstrates the feasibility of statistical modeling of climatological variables, two points should be noted. The data bases used by Wray consisted of only thirty-five data points. This tends to raise doubts as to the statistical validity of the models fitted. Also, the methodology employed in selecting the candidate distributions was highly intuitive. No rigorous, systematic procedure for selecting candidate distributions was employed. Rather, the author relied upon distributions found applicable by prior researchers and his own knowledge of statistics and statistical distributions. While the procedure does not in and of itself destroy the significance of the work, a more rigorous, systematic procedure would be preferable.

Two other individuals have made substantial contributions in this area. H. C. S. Thom (29) has made substantial contributions in investigating temperature and precipitation as well as statistical procedures used in studying meteorological phenomena. D. A. Mooley (23) has also made major contributions to the statistical study of precipitation. All available published works of these authors were studied and applicable works are incorporated into this research.

The variables maximum temperature, minimum temperature, and average temperature are discussed under the single topic, temperature. Since the studies found relating to one of these topics also applied to the other topics, this format is used to avoid repetition. All other variables are discussed individually.

Temperature

Thom and Thom (31) developed a procedure for testing monthly average temperature values for significant change over a period of time. Their work assumed that the data were normally distributed. The authors justified this assumption by reference to the work of Thom (29). In that work, the author fitted the normal distribution to monthly average temperature but did not test this fit statistically, and no alternative distributions were considered. While it could be logically argued that the normal distribution should be considered as a candidate distribution, there is no evidence given to support the conclusion that it is the only candidate or even that it is the most likely one. The author justifies his assumption by stating, "It is well known that the average monthly temperature is approximately normally distributed." No references or tests are given to support this claim of general knowledge and no other citations found in this search of the literature prior to the publishing date of these articles support this assumption. However, Thom does defend his assumption of normality by appealing to the central limit theorem. This theorem states, among other things, that averages tend to become normally distributed as the basis of the average increases.

Fortunately, Wray (36) in 1977 fitted the normal distribution to daily data on maximum, minimum, and average temperatures in the Atlanta, Georgia, location. He then tested each fit and found it to be valid. The reader is referred to the Introduction of this chapter. Wray's results support the work of Thom and Thom (31) and also the prior work of Thom (27).

Thom and Thom (31) found, in illustrating the use of this test for Boise, Idaho, over the period 1921 to 1950 versus the period 1950 to 1960, that a significant difference in norms exists. From this a trend in the variable could be inferred. Wray (36) specifically tested for this possibility in Atlanta, Georgia, and found no trends present in his data.

<u>Conclusion</u>

Thom and Thom (31) used monthly averages in their work and compared two unequal time periods. While they made no conclusion regarding the presence of trends, they did report a significant variation of monthly average maximum temperature in the period 1950 to 1960 from the average obtained during the period 1921 to 1950. It seems more logical, in view of Wray's (36) findings to conclude that the variation represents a random and quite normal fluctuation rather than a trend.

In addition, Wray's results demonstrate the feasibility of statistical modeling of the climatological variables, maximum, minimum, and average temperature. It is hoped that, through amalgamation of the data for sixteen days of the year, more statistically valid conclusions can be obtained. In addition, the behavior of the variables in more extreme climates can be compared to the results of the more moderate climate of Atlanta, Georgia.

Precipitation

Barger and Thom (2) were the first to statistically model precipitation. Their study covered the period May 17 through September 5 utilizing weekly total rainfall records over a fifty year period up to 1948. The gamma distribution was fitted to the weekly data using maximum likelihood estimators. The results indicated that the distribution could be successfully fitted to the data and that the modeling of climatological variables was a viable procedure.

Friedman and Jones (9) also modeled weekly total rainfall data. Their study covered a thirty year period up to 1954 in the Connecticut area. Their objective was to model weekly rainfall totals and from the resulting distributions, determine the probability of exceeding various rainfall amounts. The authors found that the procedure was viable and that the gamma distribution seemed to be the optimal distribution.

Mooley and Rao (23) in 1971 investigated the use of the normal and the gamma distributions to model seasonal and annual rainfall at fifty-three recording stations in India. The authors fitted both distributions to the data and tested the validity of the fit using the chi-square goodness-of-fit test. The normal distribution was found to provide a poor fit at a majority of locations studied. However, the gamma distribution was successfully fitted to the data from all fifty-three stations. Further, by use of the gamma distribution to develop rainfall probabilities, the authors found that rainfall totals could be quite accurately predicted, particularly during the monsoon season.

Building further upon this work, Mooley (24) used the gamma distribution in studying monthly rainfall totals during the summer monsoon season in Asia. The data were collected over a fifty year period from thirty-nine long-established reporting stations in those areas normally affected by monsoons. Though the author was primarily interested in the gamma distribution, other types of the Pearson distribution family were considered. Pearson types II, VIII, IX, X, XII and the normal distribution were also considered. The chi-square goodness-of-fit test, the Kolmogorov-Smirnov test, and the variance ratio test were used to determine the fit of the distribution. The results indicated that the normal distribution was not a suitable model and that such procedures as square root, cube root, and logarithmic transformations also do not apply. The gamma distribution was found to be most suitable.

Mielke (20) demonstrated the use of the kappa distribution in Climax, Colorado, to model daily rainfall amounts of precipitation However, the author used only non-zero rainfall data collected from 1965 to 1970. This limits the applicability of his findings. Further, the gamma distribution was found to yield virtually the same results and is much better known statistically.

Skees and Shenton (26), in their analysis of rainfall data over several locations in the Southeastern United States during the period 1955 to 1964, make two noteworthy summary statements.

> The statistical distribution of rainfall amounts over relatively long periods has received considerable attention in the literature; generally satisfactory fits are achieved for selected locations and seasons by using well known models such as the gamma, logarithmic normal and normal distributions. For moderate to small intervals (weeks, days, hours) satisfactory distribution models are much more difficult to find. [p. 172]

The authors go on to state that the gamma distribution has been used successfully to fit daily data in the Southeastern states, but that a better fit is obtained when using only non-zero data points.

Cornish (3) studied annual and seasonal rainfall totals for ninety-nine stations in New South Wales, Australia, over the period 1960 to 1973. The author states that the mean rainfall for the period 1943 to 1973 was above the mean rainfall for the period 1897 to 1943. The author used regression coefficients to determine if the change was significant.

Wray (36) tested for the presence of trends in his daily data on Atlanta and found no trends present. Further, the author was unable to fit any distribution to the data. The reader is referred to the Introduction of this chapter.

Conclusion

Considerably more work has been done on precipitation than on any other climatological variable. The literature indicates that the fitting of distributions to the data is viable and that the most frequently used distributions are the gamma, logarithmic normal, or some Pearson type distribution. All these distributions are considered by the methodology employed in this work.

The article by Cornish (3) raises the potential problem of trends being present in the data. Fortunately, Wray (36) specifically tested for trends in his daily data and found none present. Accordingly, the question of trends does not need to be considered since the daily data used in this study cover a period of time approximately equal to or less than the period studied by Wray.

It is hoped that, through the amalgamation of the data for sixteen days of the year, more statistically valid conclusions can be drawn. In addition, the behavior of the variable in more extreme climates can be compared to the results obtained in the moderate climate of Atlanta, Georgia.

Average Wind Speed

Luna and Church (17) applied the lognormal distribution to data from 151 recording stations scattered across the United States, Europe, Wale Island, and Puerto Rico. Depending upon the station, the data were collected over a ten to fifteen year period using hourly and half-hourly observations. The authors used graphical procedures to fit the data with the lognormal distribution and did not consider any other distributions.

The lack of a sound statistical procedure in fitting the distribution to the data and testing the fit of the distribution detracts greatly from the usefulness of the study.

Wray (36) tested the daily data obtained for the Atlanta, Georgia, location for the presence of trends and attempted to fit both the log-normal and the gamma distributions to the data. No trend was found and both distributions were fitted to the data. The reader is referred to the Introduction of this chapter.

Conclusion

The results found by Luna and Church (17) and Wray (36) indicate that statistical modeling of daily and hourly average wind speed data is feasible. The gamma and log-normal distributions have been used successfully and the methodology employed in this work encompasses these distributions. It is hoped that the amalgamation of all sixteen days of the year into a single data base for each location will allow better statistical conclusions to be obtained. In addition, the behavior of the variable in more extreme climates versus the moderate climate of Atlanta, Georgia, can be studied.

Maximum Wind Speed

Thom (28) applied the Fisher-Tippett Type II distribution to the maximum wind speed variable using data from Fort Wayne, Indiana. The author used the maximum daily wind speed value from each year over a thirty-six year period. The data do not represent any specific days. Graphical methods were used to fit the distribution to the data, though no statistical test of the fit was made.

Wood and Bowman (33) applied the Fisher-Tippett Type I distribution to daily data for the Cape Kennedy, Florida, location. The distribution was fitted using graphical techniques to several heights between 10 and 150 meters above the ground and to 2, 5, 10, 15, 30, 60, 90, and 180 day periods. The distribution was successfully applied to all data sets.

Wood, Palmer, Johnson, and Tyson (34) extended the study by Wood and Bowman (33). Daily data were collected over varying heights over a three year period at the Cape Kennedy location. Again, the Fisher-Tippett Type I distribution was successfully fitted to the data using graphical techniques.

Okulajo (25) applied the Fisher-Tippett Type I distribution to 4033 daily observations from the period 1948 to 1963 in Lagos, Nigeria. The distribution was successfully fitted using graphical techniques.

Wray (36) successfully fitted both the gamma and Fisher-Tippett Type I distributions to fifteen of the sixteen daily data bases used in his study. The author also tested for the presence of trends in the data and found that no trends were present.

Conclusion

The literature indicates that statistical modeling of maximum wind speed is a feasible approach. However, two of the three distributions that were indicated as useful cannot be considered by the methodology used in this work. These distributions are the Fisher-Tippett Type I and Fisher-Tippett Type II distributions. Fortunately, the gamma distribution has been successfully applied to daily observations of the variable and this distribution is considered through the methodology of this study.

The work performed by Okulajo (25) is particularly relevant to this study. The author uses daily observations from every day of the year over a twelve year period as a data base. This tends to indicate that useful results could be obtained from amalgamating selected daily observations from each year over a period of years. It is hoped that through this procedure the lack of data which affected Wray's work can be overcome and better statistical inferences can be drawn. In addition, it should be possible to draw conclusions regarding the behavior of the variable in more extreme climates versus the more moderate climate of Atlanta, Georgia.

Sunshine Percentage

Angell and Korshaver (1) studied the monthly average percentage of sunshine recorded at 103 recording stations throughout the contiguous United States over all months of the year during the period 1950 to 1972. They were specifically looking for variations in monthly sunshine percentage and attempted to show a relationship between this variation and the occurrence of other meteorological phenomena. The authors did not attempt to statistically model the data. Among other things, Angell and Korshaver found that sunshine followed a specific pattern over the year.

> S [percentage of possible sunshine] is at a maximum in summer and a minimum in winter with an average difference of about 20% during the two times of the year. . . . The annual variation in S is not symmetric, the decrease in S during the autumn being much more abrupt than the increase in S during the spring. [p. 1177]

Over the course of the study, the authors also found an eight percent decrease in sunshine percentage during autumn and a three percent increase in sunshine percentage during the spring, though for the entire year only a 1.3 percent decrease was found.

Wray (36) attempted to fit statistical distributions to each of the sixteen days of the year used in his study, after testing for the presence of trends in the data. No trends were found and four of the sixteen days were successfully modeled by the beta distribution. The reader is referred to the Introduction of this chapter.

Conclusion

The instruments used to record the sunlight striking the station have been improved four times during the twenty-two year period, in 1957, 1963, 1965, and 1972. The result of these changes was to allow the instrument to be operated earlier in the morning and later in the evening. Though the data recorded prior to each improvement were adjusted, the data must be considered suspect. Fog also interferes with the recording of sunshine percentage along with dust and aircraft exhaust. In fact, the latter effect, aircraft exhaust, could play a major role in confounding the data. Since most recording stations are located at airports and there has been a surge in aircraft usage over this twenty-two year period, additional concerns over the reliability of the data arise. Finally, a 1.3 percent decrease over a twenty-two year period seems more of a random long-term fluctuation than a trend.

Though the data used by Wray (36) are just as subject to questions as those used by Angell and Korshover (1), Wray's conclusions regarding trends seem to be better founded. Wray demonstrated that daily sunshine percentage could possibly be modeled with the inclusion of more data. It is hoped that the amalgamation of all sixteen days will provide the necessary data base to allow better statistical inferences. Conclusions can then be drawn regarding the behavior of the climatological variable in more extreme climates of the United States.

CHAPTER III

METHODOLOGY

Most traditional studies on this topic have been limited to a single variable. The primary weakness in this approach is that these studies treat only one dimension of the multidimensional phenomenon. A notable exception to this format was the work by Wray (36) on the climate of Atlanta, Georgia. Wray used daily data on sixteen days of the year for twelve climatological variables. A similar systems approach will be used in this investigation. The seven climatological variables incorporated in this work were maximum temperature, minimum temperature, average temperature, precipitation, average wind speed, maximum wind speed, and sunshine percentage. These variables give a reasonably inclusive view of climate at a particular location and are subject to minimal observational errors.

The work of Wray mentioned above has two weaknesses. Wray used daily observations from sixteen days of the year over a thirty-five year period. He then attempted to fit a statistical distribution to each day over the thirty-five year period. This methodology uses thirty-five data points in fitting each distribution. Statistically, his conclusions could be challenged because of insufficient data. Further, the procedure used to select candidate distributions was highly dependent upon the skill of the experimenter. Wray observed the shape of the histogram plot and used his knowledge of the shapes of the various distributions to select a candidate distribution to be fitted to the data. Basically, this is an intuitive procedure. The methodology employed in this thesis was specifically selected to eliminate these weaknesses.

Rather than fit a distribution to each of the sixteen days of the year for each climatological variable in each location, the data on each climatological variable in each location were aggregated and one distribution was fitted to the resulting data bases. This allowed the distributions to be fitted to 560 data points for the variable in Atlanta, Georgia, 314 data points for the variable in Portland, Maine, and 286 data points for the variable in Yuma, Arizona. These are all the available data and represent approximately thirty-five years of data for Atlanta, twenty years of data for Portland, and eighteen years of data for Yuma.

The procedure used in selecting candidate distributions, fitting the distributions, and testing the fit of the distributions is also different from Wray's work. Each data base, one climatological variable in one location over sixteen days of the year for all available years, was inputed to the "Frequencies" subroutine contained in the Library program, "Statistical Package for the Social Sciences" (27). This program generates the frequency histogram, minimum value, maximum value, skewness, and kurtosis. The skewness and kurtosis were then used to screen the candidate distribution in order to select the most likely candidate. The square of the skewness value was plotted with respect to the square of the kurtosis value and compared with Figure 6-1 of Hahn and Shipiro (11) (Figure 8 in Appendix A). This comparison indicated the most likely candidate distribution. The maximum likelihood estimates were then calculated for the candidate distribution to obtain the parameters of the distribution. These parameters along with the minimum and maximum values were used to calculate the area under the distributional curve. These values were then used in conjunction with the frequency histogram plot to perform the chi-square goodness-of-fit test. The detailed example of this procedure is contained in Appendix A for the variable, maximum wind speed in Portland, Maine. All variables for all locations are summarized in Chapter IV, Results and Conclusions.

CHAPTER IV

RESULTS AND CONCLUSIONS

Climatological Variable: Maximum Temperature

Atlanta, Georgia:

The analysis yielded a skewness of -0.451 and a kurtosis of -0.754. The methodology indicated that none of the distributions could be fitted to the data.

Portland, Maine:

The analysis yielded a skewness of -0.124 and a kurtosis of -0.889. The methodology indicated that none of the distributions could be fitted to the data.

Yuma, Arizona:

The analysis yielded a skewness of -0.146 and a kurtosis of 1.072. The methodology indicated that the beta (U-shaped) distribution should be fitted to the data. The resulting distributional parameters were: alpha = 4.6, beta = 1.5. However, the chi-square goodness-of-fit test indicated that the model is invalid for all values of alpha greater than .001.

Conclusions

The variability of the data prevents valid statistical modeling of the data by the procedures presented. However, the screening process by which candidate distributions were selected showed that the point defined by the skewness squared and the kurtosis squared for each location, when plotted on Figure 6-1 of Hahn and Shipiro (11), was in the region of the beta distribution or slightly above this region in the impossible area (Figure 1*). The similarities of the data from each location tend to support the conclusion that the behavior of the climatological variable, maximum temperature, is similar in each location.

By aggregating all sixteen days of the year to provide a sufficient data base for statistical analysis, the different conditions which may occur during the four seasons appear to have confounded the data to such an extent that no distribution can be fitted to the sample. The frequency histograms tend to support this hypothesis. The values of the variable are concentrated in the high regions during the summer and in the low regions during the winter. Those days which occur during the fall and spring tend to concentrate in the mid-region and blur the distinction between the winter values and the summer values. The implication is that an aggregated sixteen day sample from each year over a period of years is inappropriate in this case.

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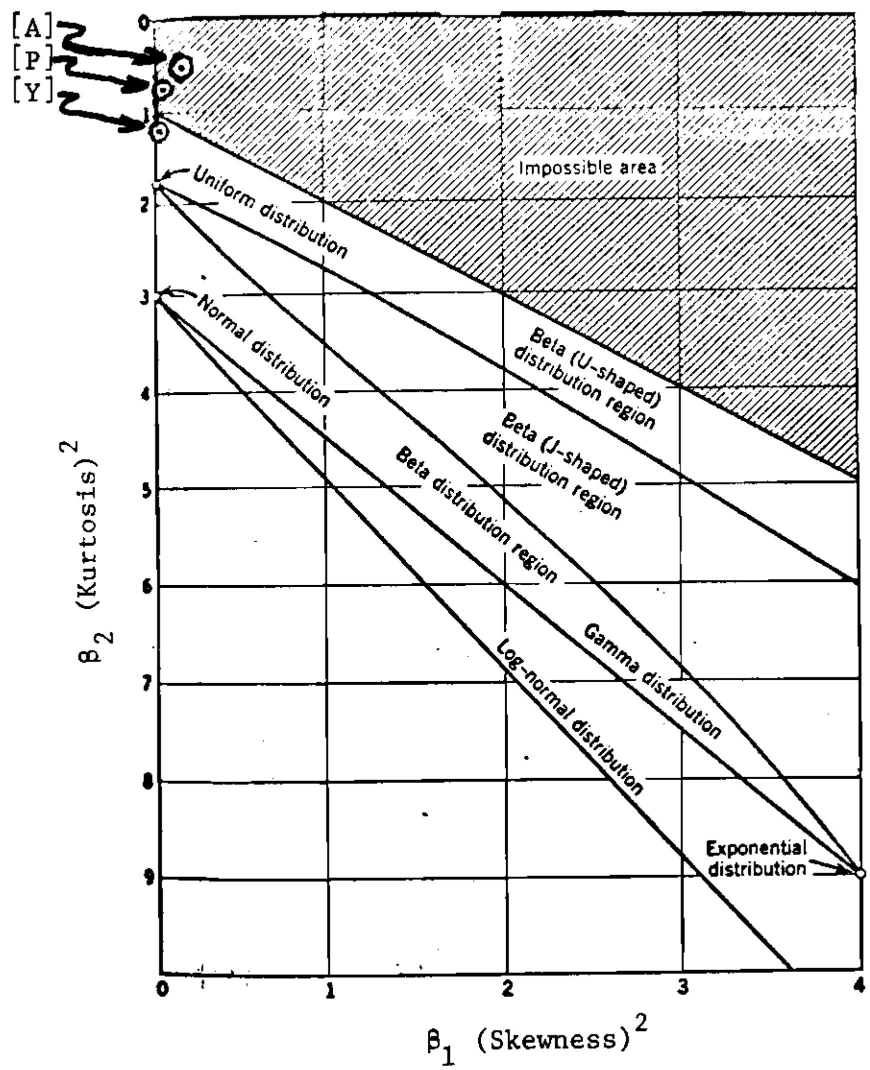
*Figures 1-6 are adapted from Hahn and Shipiro (11).



Legend: [A] = Atlanta, Georgia ($\beta_1 = 0.205$; $\beta_2 = 0.569$)
[P] = Portland, Maine ($\beta_1 = 0.015$; $\beta_2 = 0.790$)
[Y] = Yuma, Arizona ($\beta_1 = 0.002$; $\beta_2 = 1.149$)

Figure 1. Maximum Temperature Screening Chart for Candidate Distributions

Climatological Variable: Minimum Temperature

Atlanta, Georgia:

The analysis yielded a skewness of -0.329 and a kurtosis of -1.001. The methodology indicated that none of the distributions could be fitted to the data.

Portland, Maine:

The analysis yielded a skewness of -0.332 and a kurtosis of -0.517. The methodology indicated that none of the distributions could be fitted to the data.

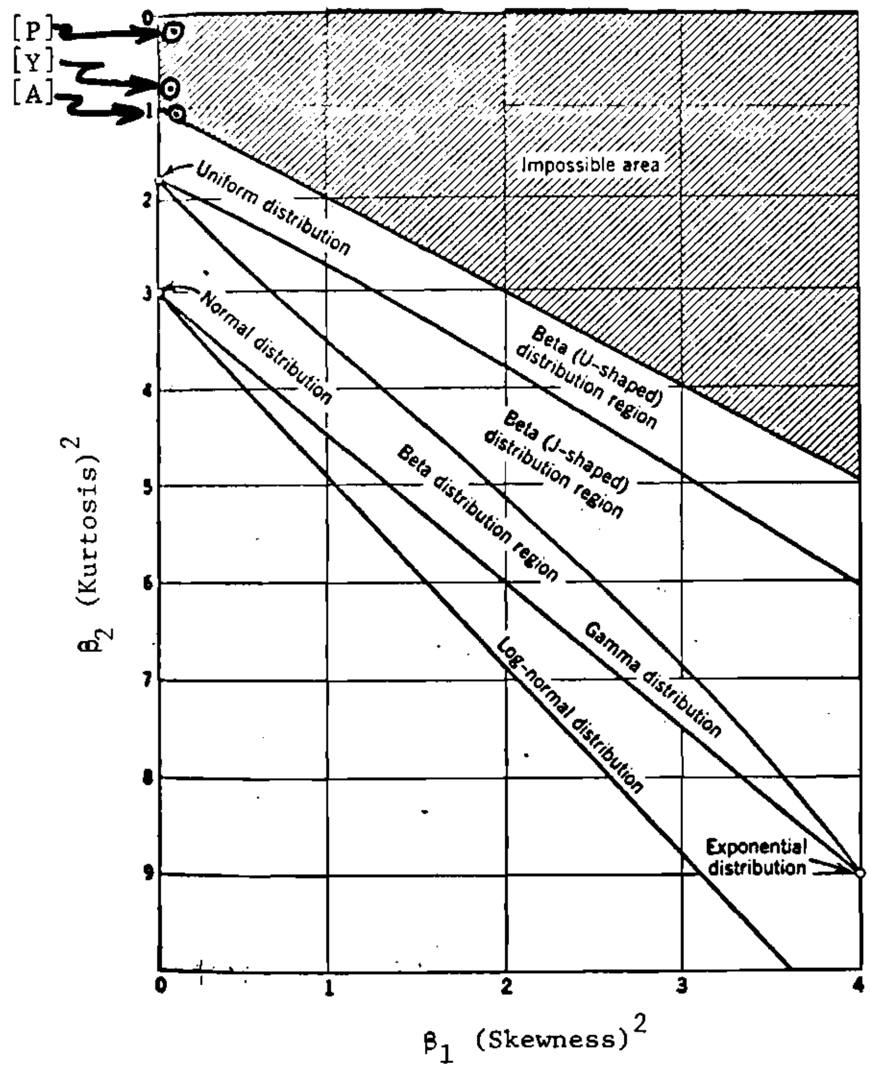
Yuma, Arizona:

The analysis yielded a skewness of -0.240 and a kurtosis of -0.923. The methodology indicated that none of the distributions could be fitted to the data.

Conclusions

The variability of the data prevents valid statistical modeling of the data by the procedures presented. However, for each location, the screening process by which candidate distributions were selected showed that the point defined by the skewness squared and the kurtosis squared, as plotted on Figure 6-1 of Hahn and Shipiro (11), was in the impossible region of the chart just above the beta region (Figure 2). The similarities of the data from each location tend to support the conclusion that the behavior of the climatological variable, minimum temperature, is similar in each location.

By aggregating the sixteen days of the year to provide a sufficient data base for statistical analysis, the different conditions which



Legend: [A] = Atlanta, Georgia (β_1 = 0.108; β_2 = 1.002)
[P] = Portland, Maine (β_1 = 0.110; β_2 = 0.267)
[Y] = Yuma, Arizona (β_1 = 0.058; β_2 = 0.852)

Figure 2. Minimum Temperature Screening Chart for Candidate Distributions

may occur during the four seasons appear to have confounded the data to such an extent that no distribution can be fitted. The frequency histograms tend to support this hypothesis. The values of the variable are concentrated in the high regions during the summer and in the low regions during the winter. Those days which occur during the fall and spring tend to concentrate in the mid region and blur the distinction between the winter values and the summer values. The implication is that an aggregated sixteen day sample from each year over a period of years is inappropriate in this case.

Climatological Variable: Average Temperature

Atlanta, Georgia:

The analysis yielded a skewness of -0.369 and a kurtosis of -0.941. The methodology indicated that none of the distributions could be fitted to the data.

Portland, Maine:

The analysis yielded a skewness of -0.265 and a kurtosis of -0.833. The methodology indicated that none of the distributions could be fitted to the data.

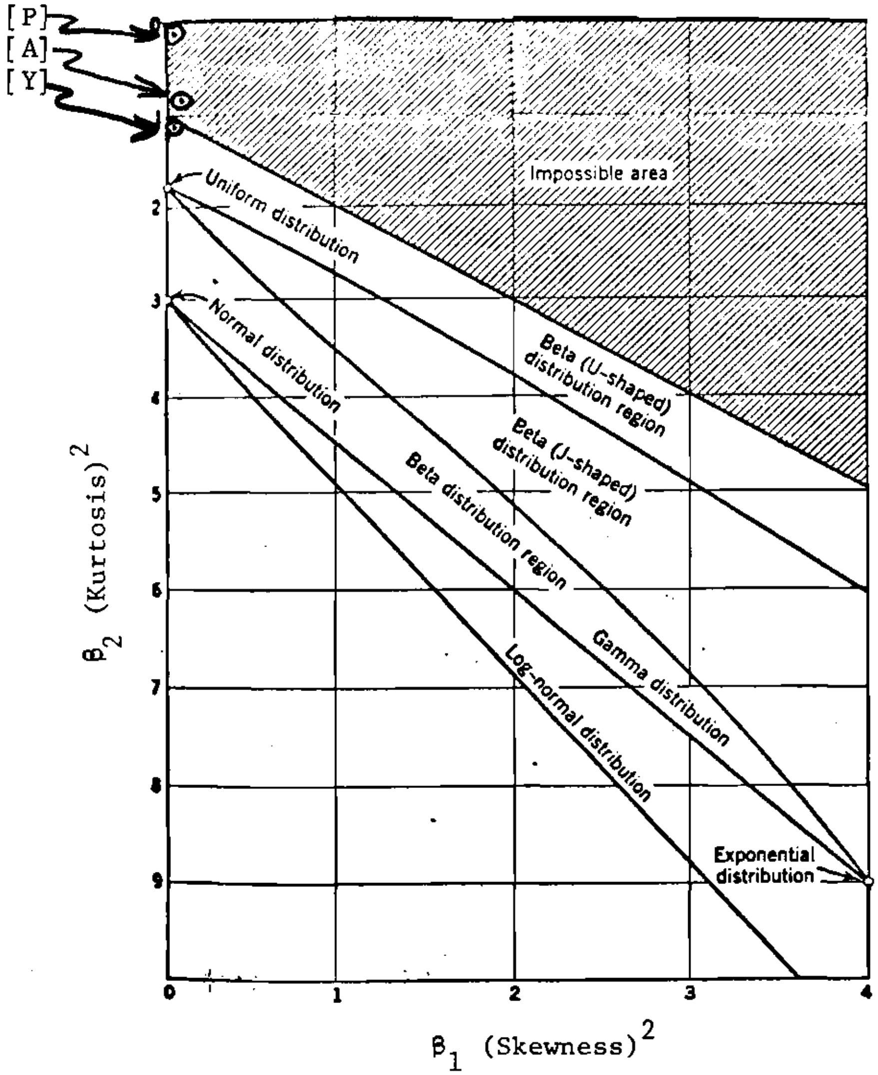
Yuma, Arizona:

The analysis yielded a skewness of -0.82 and a kurtosis of -1.087. The methodology indicated that the beta (U-shaped) distribution should be fitted to the data. The resulting distributional parameters were: alpha = 2.5, beta = 2.0. However, the chi-square goodness-of-fit test indicated that the model is invalid for all values of alpha greater than .001.

Conclusions

The variability of the data prevents valid statistical modeling of the data by the procedures presented. However, the screening process by which candidate distributions were selected showed that the point defined by the skewness squared and the kurtosis squared for each location, when plotted on Figure 6-1 of Hahn and Shipiro (11), was in the beta (U-shaped) region or in the impossible region just above the beta region (Figure 3). The similarities of the data from each location tend to support the conclusion that the behavior of the climatological variable, average temperature, is similar in each location.

By aggregating all sixteen days of the year to provide a sufficient data base for statistical analysis, the different conditions which may occur during the four seasons appear to have confounded the data to such an extent that no distribution can be fitted. The frequency histograms tend to support this hypothesis. The values of the variable are concentrated in the high regions during the summer and in the low regions during the winter. Those days which occur during the fall and spring tend to concentrate in the mid region and blur the distinction between the winter values and the summer values. The implication is that an aggregated sixteen day sample from each year over a period of years is inappropriate in this case.



Legend: [A] = Atlanta, Georgia (β_1 = 0.136; β_2 = 0.886)
[P] = Portland, Maine (β_1 = 0.070; β_2 = 0.059)
[Y] = Yuma, Arizona (β_1 = 0.007; β_2 = 1.182)

Figure 3. Average Temperature Screening Chart for Candidate Distributions

Climatological Variable: Precipitation

Atlanta, Georgia:

The analysis yielded a skewness of 4.280 and a kurtosis of 24.232. The methodology indicated that none of the distributions could be fitted to the data.

Portland, Maine:

The analysis yielded a skewness of 4.539 and a kurtosis of 26.324. The methodology indicated that none of the distributions could be fitted to the data.

Yuma, Arizona:

The analysis yielded a skewness of 14.343 and a kurtosis of 224.074. The methodology indicated that none of the distributions could be fitted to the data.

Conclusions

The variability of the data prevents valid statistical modeling of the data by the procedures presented. A study of the raw data shows that a very large number of data points have value zero. In the Atlanta, Georgia, location, 404 out of 560 data points have value zero. In the Portland, Maine, location, 210 out of 314 data points have value zero. In the Yuma, Arizona, location, 276 out of 286 data points have value zero. The high frequency of the zero value precludes any continuous distribution from being fitted. A discrete distribution, such as the Poisson, might be more appropriate.

However, the similarity of a high frequency of zero value tends to support the conclusion that the behavior of the variable, precipitation, in the extreme climates is similar to its behavior in a more moderate climate.

Climatological Variable: Average Wind Speed

Atlanta, Georgia:

The analysis yielded a skewness of 1.055 and a kurtosis of 1.400. The methodology indicated that none of the distributions could be fitted to the data.

Portland, Maine:

The analysis yielded a skewness of 0.971 and a kurtosis of 1.102. The methodology indicated that none of the distributions could be fitted to the data.

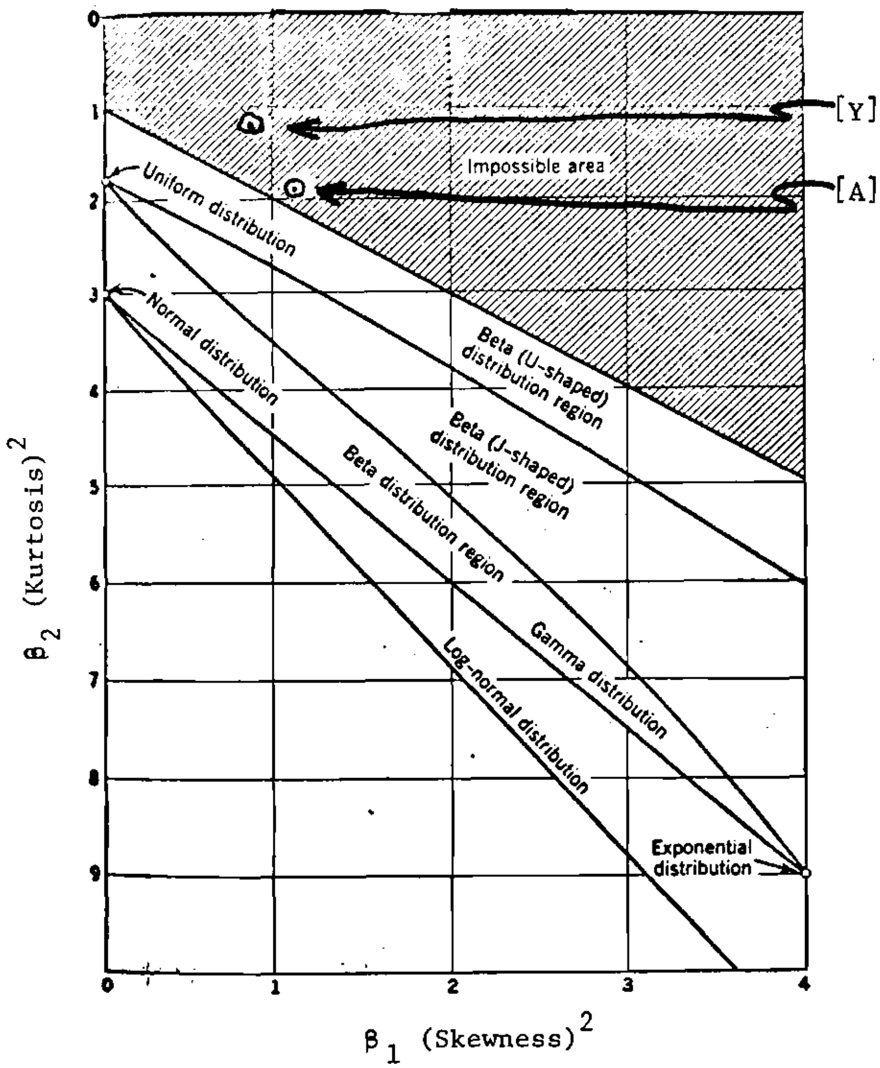
Yuma, Arizona:

The analysis yielded a skewness of 1.391 and a kurtosis of 3.456. The methodology indicated that none of the distributions could be fitted to the data.

Conclusions

The variability of the data prevents valid statistical modeling of the data by the procedures presented. However, the screening process by which candidate distributions were selected, for each location, showed that the point defined by the skewness squared and the kurtosis squared, as plotted in Figure 6-1 of Hahn and Shipiro (11), was in the impossible region of the chart for the Atlanta and Yuma locations (Figure 4). The similarities of the data from these locations tend to support the conclusion that the behavior of the climatological variable, average wind speed, is similar in each location. However, the variable appears to be

[P]--cannot be shown on chart



Legend: [A] = Atlanta, Georgia (β_1 = 1.113; β_2 = 1.96)
[P] = Portland, Maine (β_1 = 1.935; β_2 = 11.944)
[Y] = Yuma, Arizona (β_1 = 0.943; β_2 = 1.214)

Figure 4. Average Wind Speed Screening Chart for Candidate Distributions

substantially different in the Portland location and it is not clear that the phenomenon occurring is the same as at the other locations.

By aggregating all sixteen days of the year to provide a sufficient data base for statistical analysis, the different conditions which may occur during the four seasons appear to have confounded the data to such an extent that no distribution can be fitted. The frequency histograms tend to support this hypothesis. The values of the variable are concentrated in the high regions during the spring and fall and in the lower regions during the summer and winter. The implication is that an aggregated sixteen day sample from each year over a period of several years is inappropriate in this case.

Climatological Variable: Maximum Wind Speed

Atlanta, Georgia:

The analysis yielded a skewness of 1.206 and a kurtosis of 1.885. The methodology indicated that the beta (U-shaped) distribution should be fitted to the data. The resulting distributional parameters were: alpha = 4.1, beta = 2.5. However, the chi-square goodness-of-fit test indicated that the model is invalid for all values of alpha greater than .001.

Portland, Maine:

The analysis yielded a skewness of 1.118 and a kurtosis of 1.608. The methodology indicated that the beta (U-shaped) distribution should be fitted to the data. The resulting distributional parameters were:

alpha = 3.9, beta = 6.1. However, the chi-square goodness-of-fit test indicated that the model is invalid for all values of alpha greater than .001.

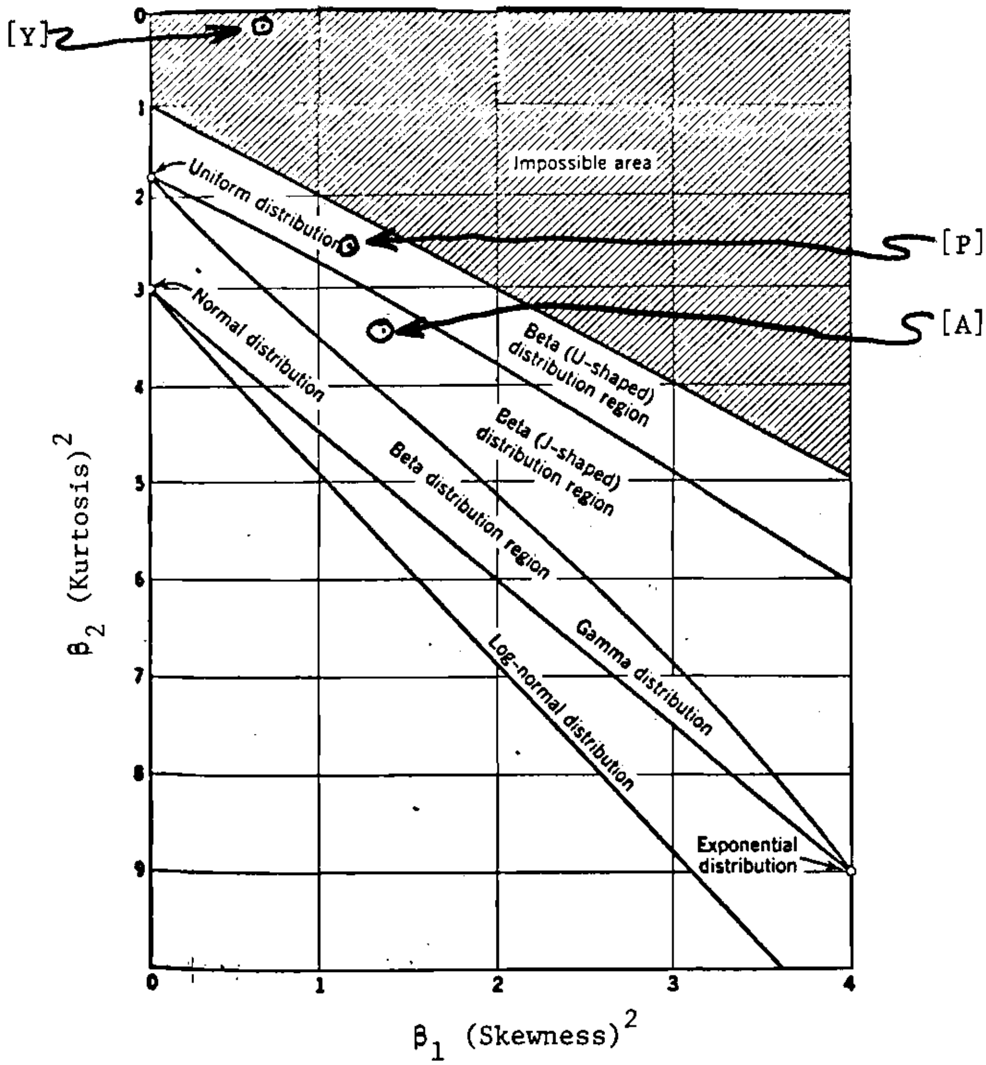
Yuma, Arizona:

The analysis yielded a skewness of 0.746 and a kurtosis of 0.314. The methodology indicated that none of the distributions could be fitted to the data.

Conclusions

The variability of the data prevents valid statistical modeling of the data by the procedures presented. However, the screening process by which candidate distributions were selected showed that the point defined by the skewness squared and the kurtosis squared, for each location, when plotted on Figure 6-1 of Hahn and Shipiro (11), was in the impossible region of the chart or in the beta region (Figure 5). The similarities of the data from each location tend to support the conclusion that the behavior of the climatological variable, maximum wind speed, is similar in each location.

By aggregating all sixteen days of the year to provide a sufficient data base for statistical analysis, the different conditions which may occur during the four seasons appear to have confounded the data to such an extent that no distribution can be fitted. The frequency histograms tend to support this hypothesis. The implication is that an aggregated sixteen day sample from each year over a period of years is inappropriate in this case.



Legend: [A] = Atlanta, Georgia (β_1 = 1.454; β_2 = 3.550)
[P] = Portland, Maine (β_1 = 1.250; β_2 = 2.586)
[Y] = Yuma, Arizona (β_1 = 0.557; β_2 = 0.097)

Figure 5. Maximum Wind Speed Screening Chart for Candidate Distributions

Climatological Variable: Sunshine Percentage

Atlanta, Georgia:

The analysis yielded a skewness of -0.642 and a kurtosis of -1.018. The methodology indicated that none of the distributions could be fitted to the data.

Portland, Maine:

The analysis yielded a skewness of 0.371 and a kurtosis of 1.303. The methodology indicated that the beta (U-shaped) distribution should be fitted to the data. The resulting distributional parameters were: alpha = 2.84, beta = 2.04. However, the chi-square goodness-of-fit test indicated that the model is invalid for all values of alpha greater than .001.

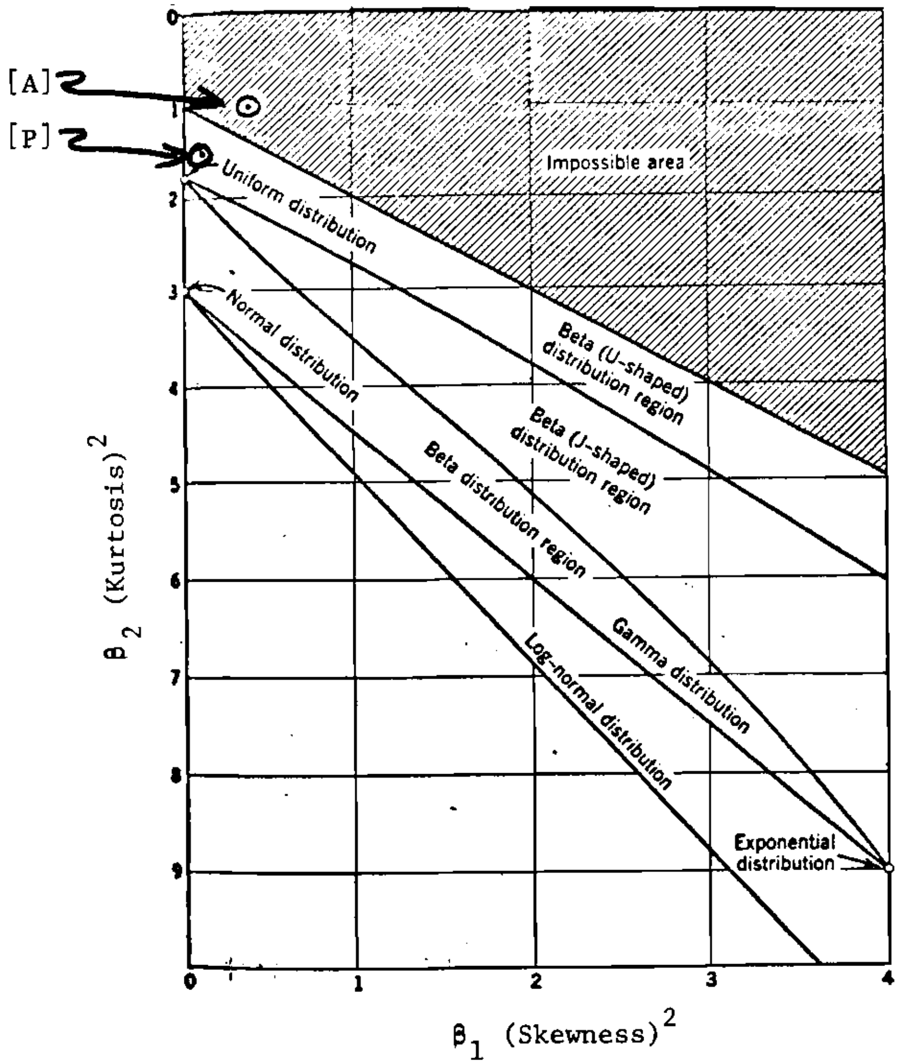
Yuma, Arizona:

The analysis yielded a skewness of -2.490 and a kurtosis of 5.931. The methodology indicated that none of the distributions could be fitted to the data.

Conclusions

The variability of the data prevents valid statistical modeling of the data by the procedures presented. However, the screening process by which candidate distributions were selected showed that the point defined by the skewness squared and the kurtosis squared, for each location when plotted on Figure 6-1 of Hahn and Shipiro (11), was in the impossible region or in the beta region of the chart (Figure 6). The similarities of the data from the Atlanta and Portland locations tend to support the conclusion that the behavior of the climatological variable, sunshine

[Y]--cannot be shown on chart



Legend: [A] = Atlanta, Georgia (β_1 = 0.412; β_2 = 1.036)

[P] = Portland, Maine (β_1 = 0.132; β_2 = 1.698)

[Y] = Yuma, Arizona (β_1 = 6.200; β_2 = 35.177)

Figure 6. Sunshine Percentage Screening Chart for Candidate Distributions

percentage, is similar in each location. However, the behavior of the variable in the Yuma location appears to be substantially different. This is probably due to the high number of maximum values that occurs in this location.

By aggregating all sixteen days of the year to provide a sufficient data base for statistical analysis, the different conditions which may occur during the four seasons appear to have confounded the data to such an extent that no distribution can be fitted. The frequency histograms tend to support this hypothesis. The values of the variable tend to be concentrated toward the higher values during the summer and toward the lower values during the winter. Those days which occur during the fall and spring show no particular pattern and blur the distinction between the winter values and the summer values. The implication is that an aggregated sixteen year sample from each year over a period of years is inappropriate in this case.

Further complicating the resolution of the data is the large number of values equal to zero or one. Since these two points represent the extremes of the variable's range, modeling by continuous distributions may be inappropriate.

CHAPTER V

RECOMMENDATIONS

The modeling of an individual day over a period of years seems to provide the most fruitful area for future research effort. This work has demonstrated that statistically modeling daily data from the selected days of the year over a period of years is not a viable procedure. Further, the modeling of daily data in weekly or monthly groups does not appear feasible because of the existence of a Markov process, weather. However, it might be possible to model all the days of the year over a period of years, as Okulajo (25) did for maximum wind speed in Lagos, Nigeria. Alternatively, it could be possible to use overlapping distributions in order to handle the seasonal effect which has apparently confounded the data. This is, however, at least an order of magnitude harder statistical problem. It is suggested that any such attempt be restricted to a single variable initially. Time series analysis also could be useful in separating out the seasonal effect which appears in the data.

The basic problem with modeling climatological variables on a specific day of the year is the lack of reliable data. For most variables, forty or fifty years of data is the maximum that can be accepted without suspicion. Prior to this, the researcher must become concerned with the devices used to measure the variable.

One approach to solving this problem could involve the use of intervals. The data could be divided into larger intervals in order to minimize the effect of a slight measurement error. For example, temperature could be divided into five degree intervals rather than reported to the nearest degree. A statistical distribution could then be fitted to the interval, and probabilities developed for the temperature falling into the interval.

Another approach would be to correct old data for measurement errors. For example, the instrument used to record sunshine percentage prior to 1950 could be reinstalled at the recording station. Measurements could be collected on both instruments so that the bias of the old instrument could be determined. Once this bias was known, old data could be corrected to more nearly reflect the variable as it is presently recorded.

Either of the methods presented could significantly increase the data base. A larger data base would allow researchers to develop more accurate and theoretically valid models. From this, more accurate probabilities could be calculated and better long term estimates of the variable could be made.

During the search of the literature, several distributions were found that were useful but could not be included in this work. Specifically, the Fisher-Tippett Type I and II extreme value distributions were demonstrated for the variable maximum wind speed. These distributions were not compatible with the systematic screening procedure used in this work and so were excluded from consideration. The inclusion of these distributions in a systematic selection procedure could improve the applicability of the procedure.

Further, only continuous distributions were considered as candidates in this work. This presents no problem for variables such as maximum temperature, minimum temperature, average temperature, average wind speed, and maximum wind speed. However, for variables such as precipitation and sunshine percentage, discrete distributions might be more appropriate. The large number of zero values in records of precipitation seems to prevent the effective modeling of the variable on a daily basis. Sunshine percentage also shows a large number of values equal to the extremes, zero and one. Johnson and Kotz (15) in their book, Discrete Distributions, give a screening chart for discrete distributions similar to the type of chart used in this work.

Precipitation has been an extensively studied subject because of its wide impact and large accurate data base. Unfortunately, precipitation in small intervals has been very difficult to model. It is possible that a different approach could yield better results. The modeling of precipitation could be approached in two phases. The first phase would be to treat the data as zero (no precipitation) or one (precipitation regardless of the amount). From this a discrete model could probably be fitted. Then the probability of any precipitation on any day fitted could be determined. The second phase could be to eliminate all zero values from the data base and then fit a distribution to the remaining data. From this the probability of precipitation amounts could be calculated. This latter phase has been done by Freedman and Janes (14) and Mielke (26).

The use of short interval totals or averages could also yield useful information. For example, precipitation totals could be obtained over a specific week for several years and a distribution fit to the weekly totals. From this, probabilities of weekly precipitation amounts could be derived. This would eliminate the large number of zero values which so complicate daily modeling.

APPENDIX A

DETAILED DATA ANALYSIS PROCEDURE FOR MAXIMUM WIND SPEED--PORTLAND, MAINE

The data on maximum wind speed for Portland, Maine, were entered into the Frequencies subroutine of the Georgia Institute of Technology Library program, "Statistical Package for the Social Sciences" (27). This program produces the frequency histogram of the data (Figure 7), finds the maximum and minimum values of the data set, and calculates the skewness and kurtosis of the data set. The maximum value is 42 and the minimum value is 7. The skewness is found to be 1.118 and the kurtosis is found to be 1.608.

In order to utilize the screening procedure outlined by Hahn and Shipiro (11), the values β_1 and β_2 must be calculated where $\beta_1 = (\text{skewness})^2$ and $\beta_2 = (\text{kurtosis})^2$. β_1 is found to be 1.250 and β_2 is found to be 2.586. The values β_1 and β_2 are then plotted on the screening chart (Figure 8). This chart was obtained from Figure 6-1 of Hahn and Shipiro (11). This point shows that the candidate distribution should be the beta distribution.

The Maximum Likelihood estimators are then used to fit the distribution to the data. The maximum likelihood estimates [Fishman (8)] are G_1 and G_2. $G_1 = e^c$ where $c = \sum_x \log(x)$ and $G_2 = e^D$ where $D = \sum_x \log(1-x)$. In this case, $G_1 = 0.384$ and $G_2 = 0.567$. By interpolating from Table A-5 of Fishman (8) (Table 1), the parameters, alpha and beta, are determined. In this case, alpha was found to be 3.9 and beta was found to be 6.1.

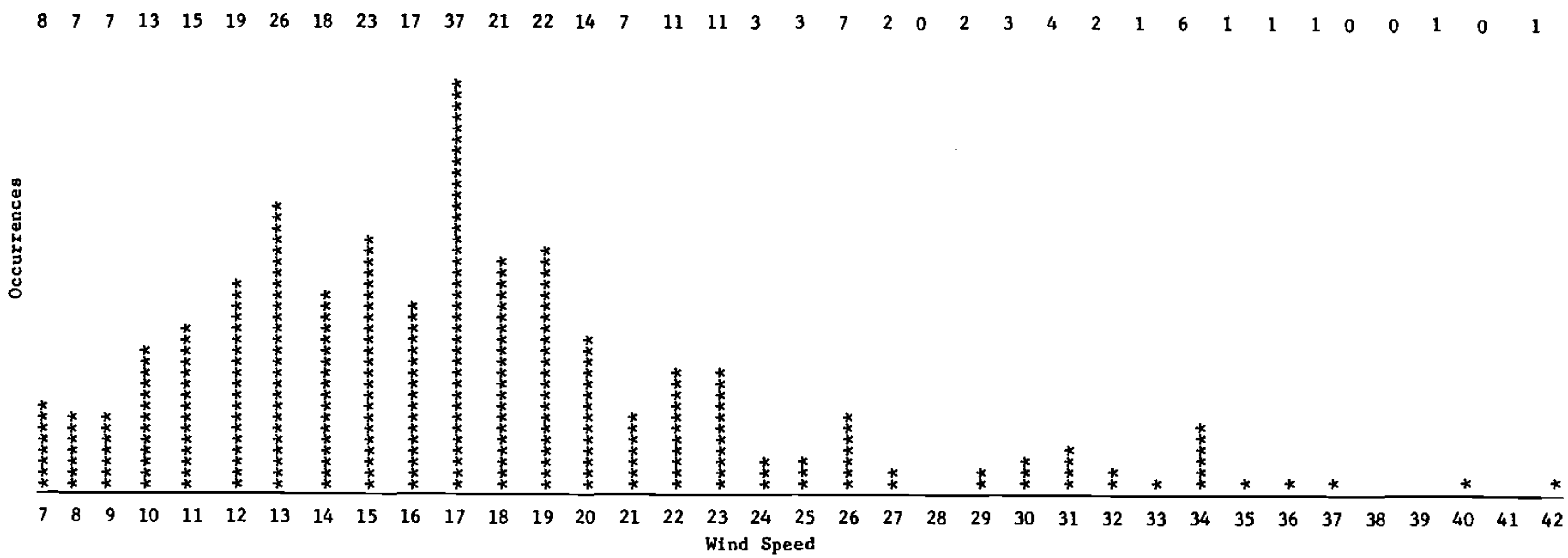


Figure 7. Maximum Wind Speed Frequency Histogram for Portland, Maine

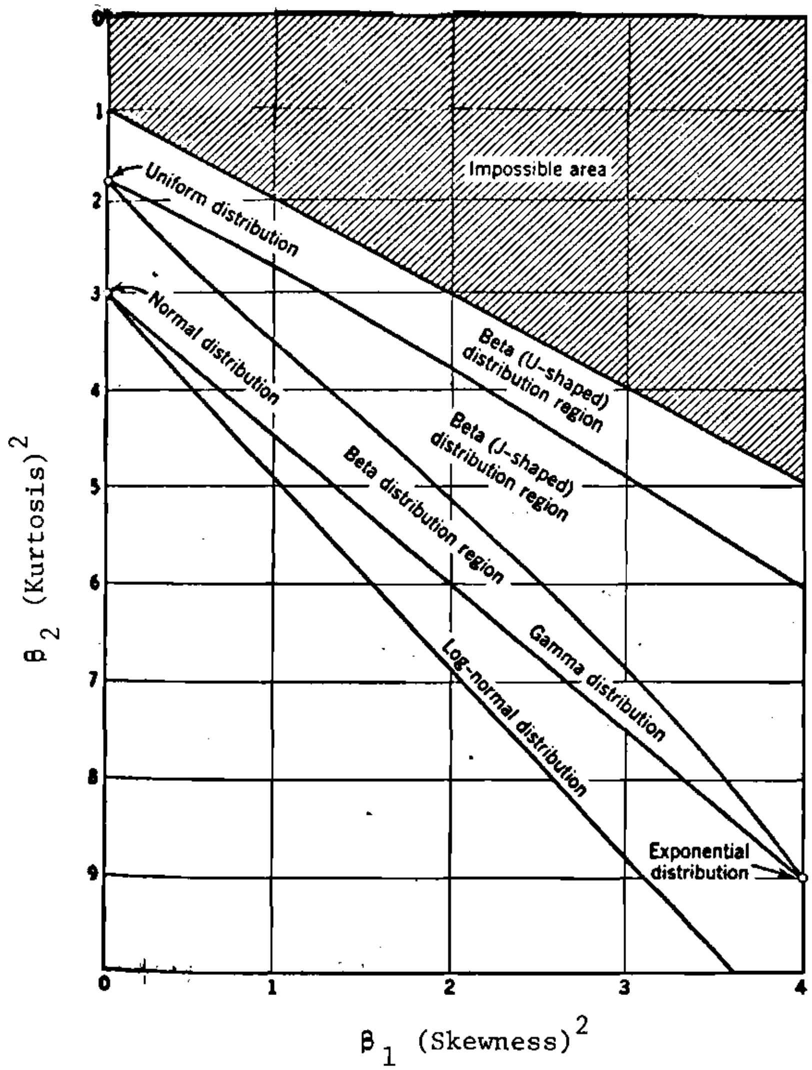


Figure 8. Screening Chart for Candidate Distributions
[Hahn and Shipiro (11)]

Table 1. Beta Parameter Interpolation Table [Fishman (23)]

Table A5 Complete Sample Maximum Likelihood Estimates of Parameters of the Beta Distribution

Range of G_1 is 0.01, 0.1(0.1)0.9. Range of G_2 is 0.01, 0.1(0.1)0.9. ($G_1 + G_2 \le 1.0$). In each cell the first entry is $\hat{\alpha}$ and the second entry is $\hat{\beta}$. ($G_1 = c^c$ and $G_2 = e^d$; see Table 23).

G_2 \ G_1	.01	.1	.2	.3	.4	.5	.6	.7	.8	.9	.98
.01	.112 .112	.192 .135	.254 .147	.318 .157	.395 .168	.495 .179	.639 .192	.877 .210	1.376 .237	3.162 .299	42.128 .850
.1		.245 .245	.337 .278	.441 .310	.576 .345	.770 .389	1.093 .451	1.756 .560	3.864 .846	* *	
.2			.395 .395	.537 .456	.735 .531	1.057 .640	1.701 .834	3.669 1.367	* *		
.3				.647 .647	.947 .804	1.532 1.086	3.280 1.869	* *			
.4					1.320 1.320	2.832 2.358	* *				
.5	BY SYMMETRY**					* *					
.6					* *						
.7				* *				NOT POSSIBLE ($G_1 + G_2 > 1$)			
.8			* *								
.9		* *									
.98											

* $G_1 + G_2 = 1$

** For example, the estimates of α and β when $G_2 = 0.2$ and $G_1 = 0.1$ are respectively the estimates of β and α when $G_1 = 0.2$ and $G_2 = 0.1$, namely 0.278 and 0.337.

Source: [153a].

Finally, it is necessary to test the fit of the distribution. The chi-square goodness-of-fit test is used for this purpose (Table 2). The area under the distribution is calculated for all possible values of the variable. The resulting probability is then multiplied by the total number of occurrences to get the expected number of occurrences for each value of the variable. The values are grouped into intervals such that each interval contains more than five expected occurrences. The corresponding number of observed occurrences is then found for each interval from the frequency histogram. The test statistic is then calculated by:

$$x = \sum \left\{ \frac{[\text{no. of expected occurrences - no. of observed occurrences}]^2}{[\text{no. of expected occurrences}]} \right\}$$

For the variable, maximum wind speed, x = 25.35. This value is larger than the chi-square value with five degrees of freedom for values of alpha greater than .001. Therefore, the chi-square goodness-of-fit test shows that the model is invalid.

Table 2. Chi-Square Goodness-of-Fit Test Data for Maximum Wind Speed Variable--Portland, Maine

no. of expected occurrences	no. of observed occurrences	$\frac{\left[\text{no. of observed occurrences} - \text{no. of expected occurrences}\right]^2}{\text{no. of expected occurrences}}$
26	15	4.65
39	35	.41
53	63	1.89
58	77	6.22
51	57	.71
39	29	2.56
26	13	6.50
22	25	.41

APPENDIX B

NARRATIVE SUMMARY OF COMPUTER SEARCH DATA BASES

DIALOG* INFORMATION RETRIEVAL SERVICE
METEOROLOGICAL AND GEOASTROPHYSICAL ABSTRACTS

FILE DESCRIPTION

METEOROLOGICAL AND GEOASTROPHYSICAL ABSTRACTS (MGA) provides current citations in English for the most important meteorological and geoastrophysical research published in both foreign and domestic literature. More than 7,000 citations taken from approximately 200 primary sources, including technical journals, monographs in series, proceedings, reviews, and annual publications, are added yearly. (¶ 29.1)

SUBJECT COVERAGE

Subjects include the following and related subjects: (¶ 29.2)

- Meteorology
- Astrophysics
- Physical Oceanography
- Hydrosphere/Hydrology
- Environmental Sciences
- Glaciology

SOURCES

Approximately 200 primary sources, both domestic and foreign, are scanned for relevant literature. They include the following: (¶ 29.3)

- Technical journals
- Reviews
- Monographs in series
- Annual publications
- Proceedings

DIALOG FILE DATA (¶ 29.4)

Inclusive Dates:	1972 to the present
Update Frequency:	Irregular, averaging 600 citations per month
File Size:	About 49,000 citations, as of June 1977

ORIGIN

METEOROLOGICAL AND GEOASTROPHYSICAL ABSTRACTS is produced by: (¶ 29.5)

American Meteorological Society
45 Beacon Street
Boston, MA 02108

The machine-readable file is made available through the Environmental Sciences Information Center, National Oceanic and Atmospheric Administration (NOAA), Washington, D.C. (¶ 29.6)

Questions concerning the computer file should be directed to: (¶ 29.7)

Mr. James Stear, Chief
Systems Branch, D826
NOAA
Washington, DC 20235

Telephone: 202/634-7335

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DIALOG* INFORMATION RETRIEVAL SERVICE

NTIS

FILE DESCRIPTION

The NTIS database consists of government-sponsored research, development, and engineering reports plus analyses, journal articles, and translations prepared by federal agencies, their contractors or grantees. NTIS also covers federally generated machine-readable files and software as well as U.S. Government inventions available for liscensing. It is the means through which unclassified, unlimited distribution reports are made available to the public. (¶ 6.1)

SUBJECT COVERAGE

The NTIS database includes material from both the "hard" and "soft" sciences, including topics of immediate, broad interest, such as environmental pollution and control, energy conservation, technology transfer, health planning, societal problems, and urban and regional development and planning. An outline of the subject coverage of this file is shown below: (¶ 6.2)

- Administration
- Aeronautics and Aerodynamics
- Agriculture and Food
- Astronomy and Astrophysics
- Atmospheric Sciences
- Behavior and Society
- Biomedical Technology and Engineering
- Building Technology
- Business and Economics
- Chemistry
- Civil Engineering
- Communication
- Computers, Control and Information Theory
- Electrotechnology
- Energy
- Environmental Pollution and Control
- Health Planning
- Industrial and Mechanical Engineering
- Library and Information Sciences
- Materials Sciences
- Mathematical Sciences
- Medicine and Biology
- Military Sciences
- Natural Resources and Earth Sciences
- Navigation, Guidance and Control
- Nuclear Science and Technology
- Ocean Technology and Engineering
- Physics
- Space Technology
- Transportation
- Urban and Regional Technology

SOURCES

Since 1964 more and more federal agencies have been announcing and selling reports through NTIS so that as of 1977, the NTIS database represents the reports of over 300 federal government agencies. (¶ 6.3)

DIALOG FILE DATA (¶ 6.4)

Inclusive Dates:	1964 to the present
Update frequency:	Biweekly (approximately 5,000 a month)
File Size:	560,000 citations, as of March 1977

ORIGIN (¶ 6.5)

National Technical Information Service (NTIS) Telephone: 703/557-4642
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22151

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DIALOG* INFORMATION RETRIEVAL SERVICE
COMPENDEX

FILE DESCRIPTION

The COMPENDEX database is the machine-readable version of *The Engineering Index**, which provides the engineering and information communities with abstracted information from the world's significant engineering and technological literature. COMPENDEX provides worldwide coverage of the journal literature, publications of engineering societies and organizations, papers from the proceedings of conferences, and selected government reports and books.

(¶ 8.1)

SUBJECT COVERAGE

COMPENDEX is an interdisciplinary index to the world's engineering developments, including the following subject areas:

(¶ 8.2)

- Civil, Environmental, Geological and Biological Engineering
- Electrical, Electronics and Control Engineering
- Chemical, Agricultural and Food Engineering
- Mining, Metals and Fuel Engineering
- Mechanical, Automotive, Nuclear and Aerospace Engineering
- Industrial and Management Applications

SOURCES

Publications from around the world are indexed, among which are the following types:

(¶ 8.3)

- Approximately 1800 journals
- Publications of engineering societies and organizations
- Approximately 1000 works from conferences, symposia, etc.
- Selected government reports and books

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APPENDIX C

LOCAL CLIMATOLOGICAL DATA SUMMARIES

Yuma, Arizona

The climate of Yuma is definitely a desert product. During the winters, home-heating is necessary from late October until the 10th of April; but work or play can be conducted comfortably out-of-doors from about 10 a.m. to 5 p.m. during the winter, which is a period of mostly clear skies and abundant sunshine. Frosts are not uncommon in the nearby valleys and must be expected occasionally on higher lands.

In the period from November 1 to April 1 there are, on the average, 16 daylight hours with rain, a little more than three a month. There are places in the world where more rain has fallen in a single year than has fallen at Yuma during the past 90 years.

The sun does not shine all of every day, but comes nearer doing so at Yuma than any other place in the United States for which we have records. Even in December and January the lower Colorado River Valley averages better than eight hours of sunshine a day.

The summers in this country are long and hot. Afternoon temperatures reach 100°, on the average, from June 10 to September 20, and 105° from July 2 to August 14. An extreme of 120° has been reached four times and the absolute high of 123° was registered on September 1, 1950.

The hot air, ballooning upwards, draws in moisture-laden air from the Gulf of Lower California. Water content of the air from mid-July to mid-September is higher than might be expected over a desert area. This condition results from the relative nearness to the Gulf of Lower California. Evaporative coolers are very effective for cooling purposes during all the months except July, August, and September, during which months the wet bulb temperatures are frequently between 75° and 80° -- a condition that makes the ordinary water cooler somewhat ineffective.

EXTREME WEATHER CONDITIONS RECORDED AT YUMA ARE INDICATED BELOW.

The greatest number of consecutive days with:

Maximum temperature 90° or higher, 153 in1973.
Maximum temperature 100° or higher, 101 in 1937.
Maximum temperature 110° or higher, 14 in 1955.
Minimum temperature 32° or lower, 8 in 1913.
Minimum temperature 80° or higher, 30 in 1959.
Rainfall 0.01 inch or more, 7 in 1897.
No rainfall as great as 0.01 inch, from December 29, 1879, to December 15, 1880, 351 days.

Other statistics show:

Yuma's warmest day with a mean temperature of 103.5° was recorded on July 31, 1957.

Warmest month was July 1959 with a mean temperature of 96.7°. The average maximum was 109.4°, and the minimum temperature averaged 83.9°.

Warmest year was 1958 with a mean temperature of 76.3°. The average maximum temperature was 90.6°, and the minimum averaged 61.9°.

Coldest day was January 6, 1913, with a mean temperature of 31°. The maximum temperature reading was 38° and the minimum temperature was 24°.

Coldest month was January 1937 with an average of 44.9°. The maximum temperature averaged 55.9°, and the minimum 33.9°.

Coldest year was 1909 with an average of 70.4°+. The average maximum was 85.7° and the minimum 55.2°.

Highest temperature ever recorded at Yuma was 123° on September 1, 1950.

Lowest temperature ever recorded at Yuma was 22° on January 24, 1937, December 26, 1911, and January 20, 1883.

Wettest year on record, 1905 with 11.41 inches of rainfall.

Driest year on record, 1956 with 0.30 inch of rainfall.

Snow entries in the records indicate a trace in December 1932, January 1937, and December 1967.

Portland, Maine

As a rule, Portland has very pleasant summers and falls, cold winters with frequent thaws, and disagreeable springs. Very few summer nights are too warm and humid for comfortable sleeping. Autumn has the greatest number of sunny days and the least cloudiness. Winters are quite severe, but begin late and then extend deeply into the normal springtime.

Heavy seasonal snowfalls, over 100 inches, normally occur about each 10 years. True blizzards are very rare. The White Mountains, to the northwest, keep considerable snow from reaching the Portland area and also moderate the temperature. Normal monthly precipitation is remarkably uniform throughout the year.

Winds are generally quite light with the highest velocities being confined mostly to March and November. Even in these months the occasional northeasterly gales have usually lost much of their severity before reaching the coast of Maine.

Temperatures well below zero are recorded frequently each winter. Cold waves sometimes come in on strong winds, but extremely low temperatures are generally accompanied by light winds.

The average freeze-free season at the airport station is 139 days. May 12 is the average date of the last freeze (32°) in spring, but this has been as early as Arpil 22 and as late as May 31. The average date of the first freeze in fall is September 27, with the earliest and latest occurrences on September 17 and October 10. The freeze-free period is longer in the City proper, but may be even shorter at susceptible places further inland.

The Portland City Airport is located 2-3/4 miles west of the site of the former city office. The surrounding country is mostly open, rolling and sloping generally toward the Fore River, a body of brackish water about 1,000 feet wide at a distance of about 1/2 mile from the station and forming one boundary (north through east) of the field. The airport is about 5-1/2 miles west-northwest of the open ocean. A slight rise reaching an elevation of 100 feet, lying northwest of the field, cuts down the wind slightly from that direction. The older portion of the City is situated on a hill rising abruptly from sea level to 170 feet, 1-1/2 miles east of the airport and on the opposite side of the Fore River. A line of low hills southeast of the airport, near the ocean, which reach a maximum height of 160 feet, shuts off sight of the ocean from the airport. Sebago Lake with an area of 44 square miles is situated about 15 miles to the northwest and 45 miles farther are the White Mountains, averaging 3,000 to 5,000 feet in height.

Daily maximum temperatures at the present airport site agree closely with those near the former intown office, but minimum temperatures on clear, quiet mornings range as much as 15° lower at the airport.

The city of Atlanta with an elevation of approximately 1,000 feet above sea level is located at the foot of the Blue Ridge Mountains. Consequently, the terrain is rolling to hilly. As the land slopes downward both to the east and west, as well as to the south of Atlanta, the drainage from this area in the eastern part of the City flows into the Yellow River and on into the Atlantic Ocean through the Altamaha system, while that to the west and south enters the Gulf of Mexico by way of the Apalachicola River from the Chattahoochee and Flint Rivers.

The climate of Atlanta is modified by its altitude and proximity to the Atlantic Ocean and the Gulf of Mexico. This modification tends to temper the continental winter cold as well as the high temperatures of summer. Also, the mountains along the northern border of Georgia and in Tennessee act as a partial barrier to the southward movement of outbreak of cold continental air during winter months so that sudden large changes to lower temperatures are rare. The cold air normally being delayed by these mountains has sufficient time to be considerably modified prior to its arrival over Atlanta. Temperatures have fallen below zero on rare occasions, but the lowest normal daily minimum temperatures are above freezing. The effect of its altitude on Atlanta's summer temperatures is that the days, and even to a greater extent the nights, are much more comfortable than those at cities a short distance to the south over lower terrain.

This City is located in or close to the humid subtropical climate belt. Thus, precipitation is plentiful for the growth of most crops, although dry periods of several weeks to a month's duration are not uncommon. These dry periods occur most often in the late summer or early autumn, and periods of pleasant mild weather are quite common. Since the beginning of records, snow has been observed during seven of the twelve months of the year, but it occurs so rarely in measurable amounts and remains on the ground for so short a time that it is of little importance as a climatic factor. Ice storms (freezing rain or glaze) are not uncommon during the winter months, but are seldom of an intensity to produce any considerable damage. Their life span is normally of short duration. During this type storm, the freezing line is usually near Atlanta and the zone of icing is narrow. The dividing line between ice and no-ice is often so sharply defined and narrow that icing occurs over parts, but not all of the City.

The surface winds are normally strong enough for adequate ventilation of the City, but are seldom of a speed so as to be unpleasant or damaging. The east to northeast winds during the colder part of the year produce the most unpleasant weather that occurs in this area. Winds from this direction often bring in low clouds, some rain, and temperatures low enough to produce raw, disagreeable weather. Winds from the south are naturally warm and moist both summer and winter. During the summer these southerly winds produce uncomfortably high humidities. The highest summer temperatures for the area occur with the somewhat drier westerly winds.

The dates of the last freezing temperature in spring and of the first in autumn mark the limits of the growing season for most crops, but several market crops may frequently be grown all winter in this vicinity with slight protection. The average growing season is 233 days from March 24, which is the date of the last freezing temperature in the spring, to November 13, the date of the first freezing temperature in autumn.

Thunderstorms which may occur in any month are most frequent in the summer. Heavy fogs seldom occur, and during the summer months even light fogs are infrequent. Thus, the average number of clear to partly cloudy days greatly exceed the average number of cloudy days, making Atlanta a sunny place to live.

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